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GB 307681
GB 228914
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(71) Applicant
Michael Joseph French, 4 Haverbreaks Place, Lancaster LA1 5BH
(72) Inventor
Michael Joseph French
(74) Agent
John Edward Alderman

(54) A device for extracting energy from waves

(57) A device 10 for extracting energy from waves on a liquid, comprises a train of panel members 14, 15 aligned in the direction of motion of the waves and exposed on one side to the waves. The panel members are bodily displaceable laterally in response to variations in hydrostatic pressure on them from the waves, and thus vary the volume of pumping chambers defined by bellows 19*a*, 19*b* in a pneumatic or hydraulic circuit so as to perform useful work by displacing a fluid in the circuit through a turbo-generator 37.

Two parallel trains of panel members on opposite sides of the device may be used and arranged to share a common pneumatic or hydraulic circuit.

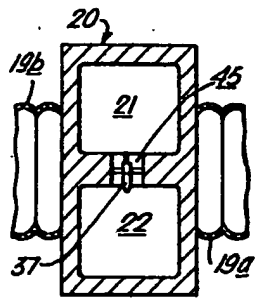

Fig. 1a.

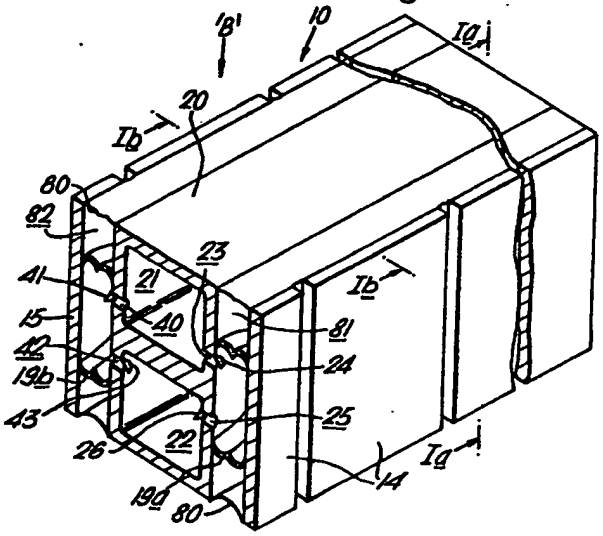

Fig. 1.

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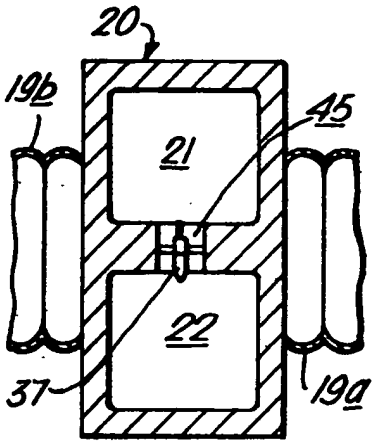
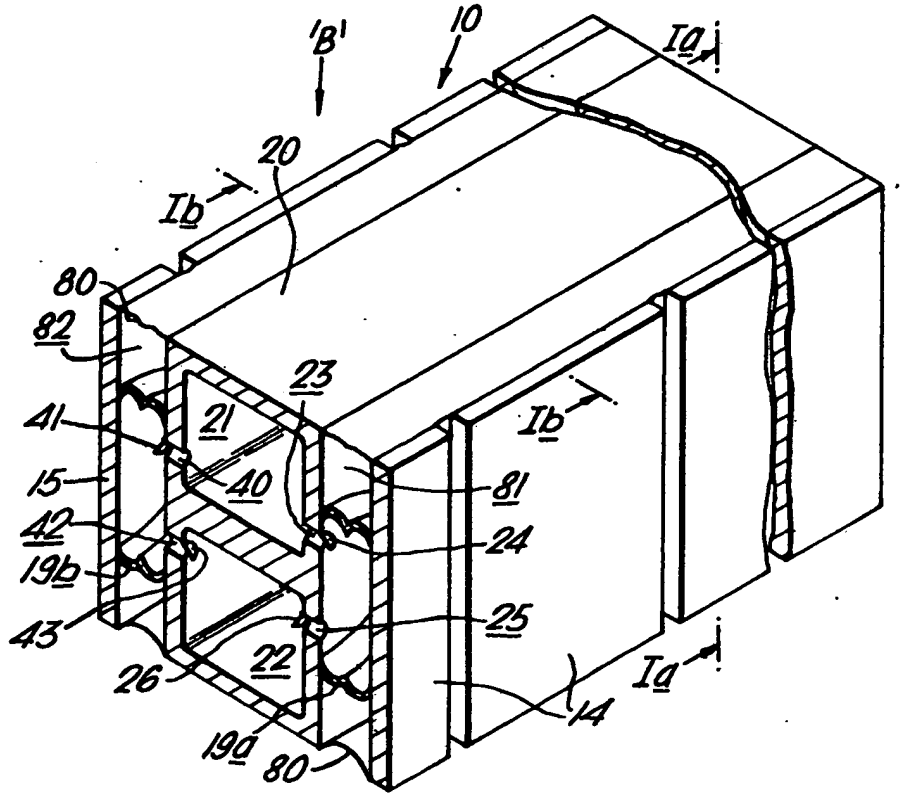

20
19b
45
21
22
37
19a

Fig. 1a.

Fig. 1.


B
10
Ia
20
Ib
80
82
23
41
21
Ib
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19b
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Ia
26
14
19a
80

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Fig. 1b.

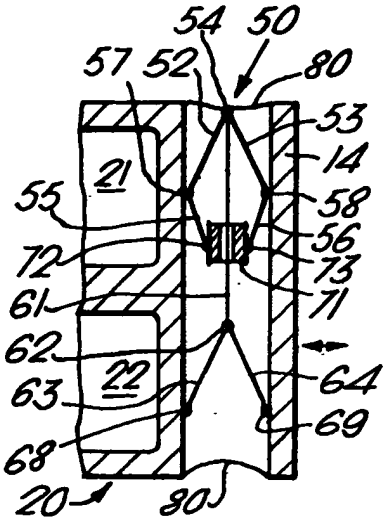


Fig. 1d

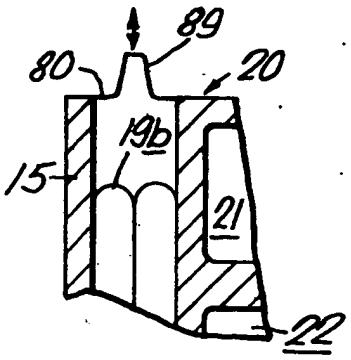


Fig. 1c.

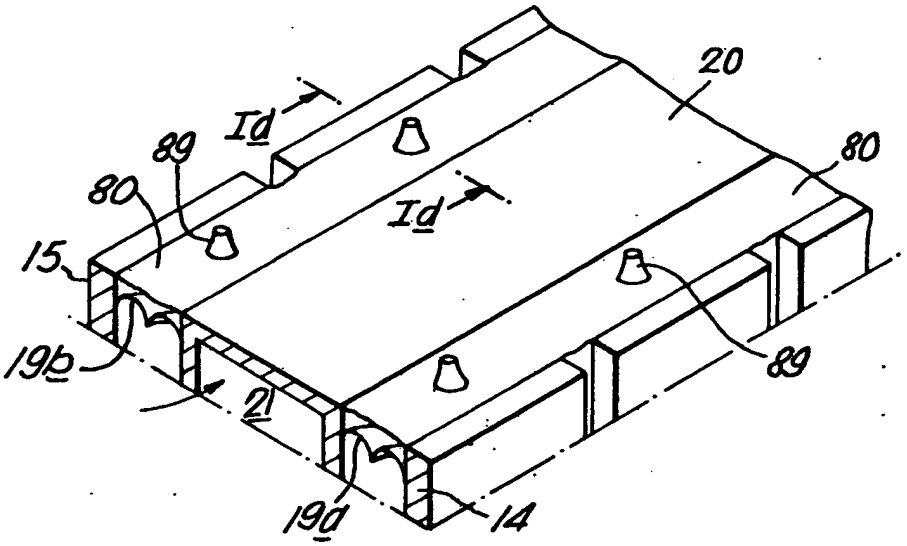


Fig. 2.

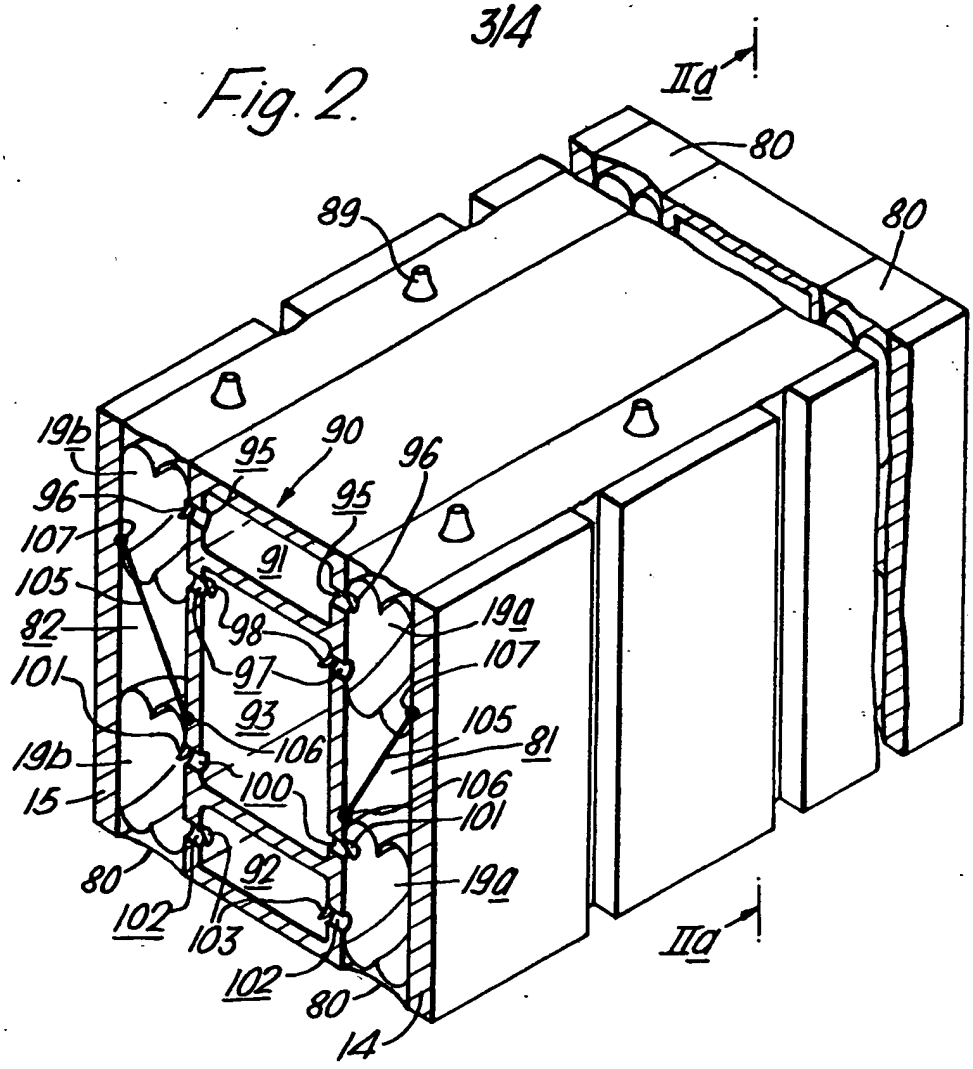


Fig. 2a

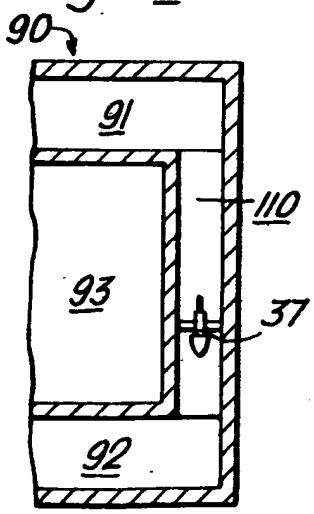


Fig. 2b.

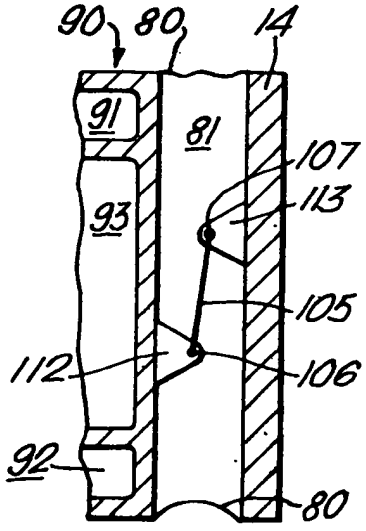


Fig. 3a.

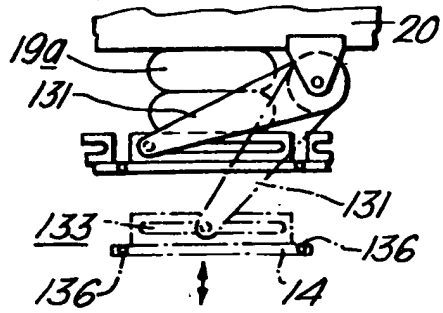
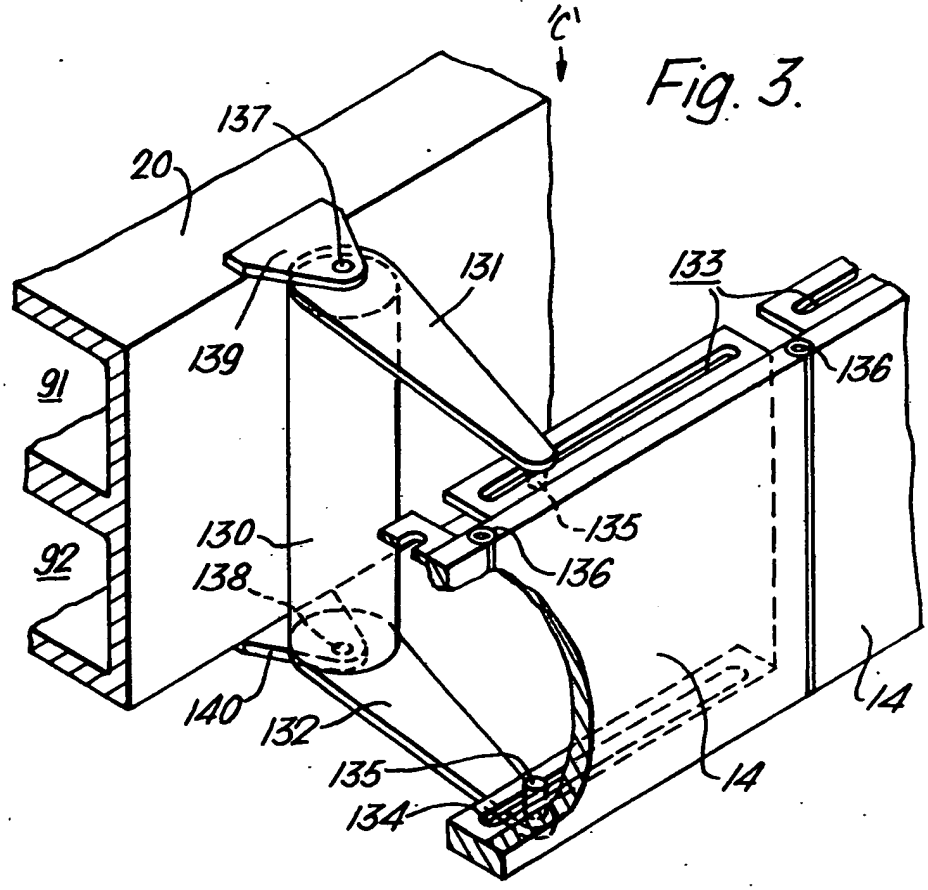

20
19a
131
131
133
136
136
14

Fig. 3.


C
137
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SPECIFICATION

A device for extracting energy from waves

This invention relates to a device for extracting energy from waves on a liquid.

An example of such a device is described in co-pending application No. 21768/76, and relates to the use of a number of chambers in a flexible air-filled tube which is moored in a liquid and in the direction of motion of waves. Fluctuations in the hydrostatic pressure on the tube are used to circulate air from the chambers through a pneumatic circuit which includes a turbine so that electrical energy can be produced from energy extracted from the waves. The present invention is an improvement of the aforedescribed device.

According to one aspect of the present invention, there is provided a device for extracting energy from waves on a liquid, the device comprising at least one panel member substantially of rigid form, the panel member being arranged so as to be aligned in use substantially in the direction of motion of the waves and be exposed on one side thereof to the waves so that laterally in one direction the panel member is displaceable bodily by the pressure of the waves thereon, means for performing useful work from lateral displacement of the panel member, and means for urging return lateral displacement of the panel member as the wave pressure on said one side of the panel member falls.

According to another aspect, the invention also provides a device for extracting energy from waves on a liquid, the device comprising a train of panel members, each panel member being substantially of rigid form and the panel members being hingedly connected together at adjacent edges thereof, means for presenting each panel member upwardly in use and such that laterally thereof the panel member is displaceable bodily, means comprising a fluid circuit for performing useful work from lateral displacement of the panel members, and means for urging return lateral displacement of the panel members, the device in use being arranged so as to align the train substantially in the direction of motion of the waves so that the variations in hydrostatic pressure on the panel members as the waves pass along one side of the train lead laterally of the panel members to bodily displacement thereof.

Desirably, the device includes means for constraining to substantially parallel motion the lateral displacement of the panel member, and the constraining means may comprise linkage means, preferably parallel-motion linkage means.

Advantageously, a train of said panel members may be provided and arranged so as to be aligned in use substantially in the direction of motion of the waves, and in one application of the invention two said trains are distributed one said train one side of the device and the other said train on the opposite side of the device. The panel members of the trains desirably share a common work performing means.

The panel members may be of buoyant construction, or substantially of neutral buoyancy.

The work performing means may comprise a fluid circuit including at least one chamber at each panel member, said chamber having a volume arranged to be varied with said lateral displacement of the respective panel member so as to pressurize a fluid in the fluid circuit. In the preferred form of the invention, the fluid circuit comprises a pneumatic circuit, and includes a turbine means arranged to be driven by pressurized gas in the pneumatic circuit. At least some of the chambers may be connected together in series relationship.

The return urging means may comprise resilient means, and may also comprise a portion of said fluid or pneumatic circuit, said portion being arranged to discharge said fluid or said gas into the chambers so as to expand said chambers.

Flexible impermeable material desirably extends around the or each panel member to define an air filled space on the other side of the panel member, so as to inhibit the ingress of the liquid to said other side of the panel member. At least one air vent may be included for said space, and an air turbine means may be arranged to be driven by the air venting through the air vent.

In yet a further aspect, the invention includes a method of extracting energy from waves on a liquid, the method comprising presenting at least one panel member substantially in the direction of motion of the waves and exposing one side of the or each panel member to the waves, allowing the or each panel member laterally thereof to be displaced bodily by the waves thereon, and performing useful work from lateral displacement of the or each panel member. A plurality of said panel members may be presented in a train and the train aligned substantially in the direction of motion of the waves. Adjacent panel members may be hingedly connected together so that the train undulates along the length of the train in response to the variations in hydrostatic pressure thereon.

The invention will now be further described by way of example only with reference to the accompanying drawings in which:—

Figure 1 shows a perspective part-sectional representation of a device for extracting energy from waves;

Figure 1*a* shows a fragmentary sectional view on the line Ia—Ia of Figure 1;

Figure 1*b* shows a fragmentary sectional view on the line Ib—Ib of Figure 1;

Figure 1*c* shows a fragmentary view in the direction of arrow 'B' of Figure 1;

Figure 1*d* shows a fragmentary sectional view on the line Id—Id of Figure 1*c*;

Figure 2 shows a perspective part-sectional representation of an alternative device to that of Figure 1;

Figure 2*a* shows a fragmentary sectional view on the line IIa—IIa of Figure 2;

Figure 2*b* shows an alternative sectional view of part of the device of Figure 2;

Figure 3 shows a perspective fragmentary representation of a modification of the device of Figure 1; and

Figure 3*a* shows a fragmentary view in the direction of arrow 'C' of Figure 3.

In the above Figures, like parts have like numerals.

Referring now to Figure 1, a device 10 is shown having side plates 14, 15 of rigid form, and a rigid spine in the form of a plenum member 20 having two ducts 21, 22 respectively. A bellows 19*a* is bonded at one end to each side plate 14 and at its other end is bonded to the plenum member 20, and an identical bellows 19*b* is bonded to each side plate 15 and to the plenum member 20. Each bellows 19*a* is connected to the duct 21 by an inlet 23 having a non-return valve 24, and to the duct 22 by an outlet 25 having a non-return valve 26. Each bellows 19*b* is connected to the duct 21 by an inlet 40 having a non-return valve 41, and to the duct 22 by an outlet 42 having a non-return valve 43.

Referring to Figure 1*a*, the ducts 21, 22 are connected by a duct 45 having a turbo-generator 37 therein arranged to be driven by air flow from duct 22 into duct 21. Each side plate 14 as shown in Figure 1*b* to which reference is now made, is constrained to move laterally in a parallel manner by a parallel-motion linkage 50 (only one is shown) located near each upwardly directed edge of the side plates 14. The linkage 50 comprises two links 52, 53 of equal length joined together by a hinge 54 and hingedly connected by respective hinges 57, 58 to respective links 55, 56, each of the same length as links 52, 53, hinge 57 being attached to the plenum member 20 and hinge 58 being attached to the side plate 14. An elongate centre link 61 has one end joined to the hinge 54 and has its other end connected to a hinge 62, to which links 63, 64, each of the same length as links 52, 53, are hingedly connected at one end thereof. The other ends of the links 63, 64 are hingedly connected to respective hinges 68 and 69, hinge 68 being attached to the plenum member 20 and hinge 69 being attached to the side plate 14. A slider member 71 slidably locates around the centre link 61, and has hinges 72 and 73 to which the respective links 55, 56 are hingedly connected.

An identical parallel-motion linkage 50 is provided between each side plate 15 (not shown) and the plenum member 20.

A flexible impermeable sheet 80 of a material such as plastics coated cloth, is bonded to the upper, lower, and side edges of the plenum member 20 and the respective side plates 14, 15, and to the adjacent sides of the side plates 14, 15 to enclose air-filled buoyancy spaces 81, 82 respectively. The air in the buoyancy spaces 81, 82 may remain trapped therein, or may be vented as shown in Figure 1*c*, and 1*d*, through a plurality of vents 89. In order to maximise the energy extracted from the waves, the vents 89 may be arranged to discharge through a turbo-generator (not shown).

In operation, the device of Figure 1 is moored in the sea with the side plates 14, 15 aligned in the direction of motion of the waves, and is ballasted (not shown) so as to be partially submerged with the tops of the side plates 14, 15 slightly above the crests of the highest waves. As the waves pass along the device, each side plate 14, 15 laterally thereof is displaced bodily as a result of the variations in hydrostatic pressure thereon as wave crests and wave troughs pass along. The side plates 14, 15 compress the respective bellows 19*a*, 19*b* at the higher hydrostatic pressures, and the bellows 19*a*, 19*b* discharge pressurized air through the respective outlets 25, 42 into the duct 22 from which the pressurized air flows through the turbo-generator 37 and is discharged at a lower pressure into the duct 21. With decreasing hydrostatic pressure on the side plates 14, 15, a stage is reached when this decreasing pressure is insufficient to overcome the pressure of the lower pressure air in the duct 21 and this air therefore flows through the respective inlets 23, 40 to return into and expand the bellows 19*a*, 19*b* and thus causes return lateral displacement of the side plates 14, 15. Because of the effect of the parallel motion linkages 50, the side plates 14, 15 are constrained to move laterally in a parallel manner.

The invention has been described in relation to the use of a single row of bellows 19*a*, 19*b* distributed along the length of the device 10, but a plurality of such rows located one above the other may be used as shown in Figure 2 to which reference is made.

In Figure 2, the device shown has side plates 14, 15, disposed about a plenum member 90 having an upper duct 91, a lower duct 92, and an intermediate duct 93. Two bellows 19*a*, 19*b* are disposed one above the other between each side plate 14 or 15 and the plenum member 90. The upper of the two bellows 19*a*, or 19*b* is connected to the duct 91 by an inlet 95 having a non-return valve 96, and to the duct 93 by an outlet 97 having a non-return valve 98. The lower of the two bellows 19*a* or 19*b* is connected to the duct 93 by an inlet 100 having a non-return valve 101 and to the duct 92 by an outlet 102 having a non-return valve 103. Two links 105 (only one is shown) are hingedly connected at one end to a hinge 106 at the plenum member 90 and at the other end thereof to a hinge 107 at each respective side plate 14 or 15, the links 105 being distributed one each side of the bellows 19*a* or 19*b*.

As shown in Figure 2*a* to which reference is made, the ducts 92 and 91 are connected at one end by a duct 110 in which a turbo-generator 37 is situated so as to be driven by air flow from duct 92 to duct 91 through the duct 110.

In other respects the device of Figure 2 resembles that of Figure 1, having a sealing membrane 80 between each side plate 14, 15 and the plenum member 90, and having air vents 89.

In operation, lateral displacement of the side plates 14, 15, as a result of waves passing along the side plates 14, 15, compresses the respective bellows 19*a*, 18*b*, and the side plates 14, 15 are

subsequently moved outwardly by the extension of the bellows 19*a*, 19*b* in a similar manner to that described in relation in Figure 1. Air flows from the upper row of bellows 19*a*, 19*b*, into the intermediate duct 93, from the intermediate duct 93 into the lower row of bellows 19*a*, 19*b*, and subsequently therefrom into the lower duct 92 from which it flows through the duct 110, thereby driving the turbo-generator 37, into the upper duct 91 from which it recycles through the device. Although there is a vertical component of the rotary motion of the links 105, none the less lateral displacement of the side plates 14, 15 occurs in a substantially parallel manner.

The side plates 14, 15, of Figure 2 may be of buoyant construction, the links 105 restraining upward displacement of the side plates 14, 15, except for the aforesaid vertical component of the rotary motion of the links 105. In order to reduce this vertical component as shown in Figure 2*b* to which reference is made, the hinges 106 and 107 may be situated in lugs 112, 113 extending from the plenum member 90 and the side plate 14, or 15 (not shown) respectively to arrange that each link 105 moves through a substantially equal angular displacement in either direction about a mean vertical position of the link 105, the bellows 19*a* being omitted for clarity in Figure 2*b*.

Use of the links 105 may be dispensed with if the side plates 14, 15, are suitably ballasted to provide a neutral buoyancy. It will also be understood that, buoyant or neutral side plates 14, 15 may be used in the device 10 or Figure 1.

A device having an alternative arrangement to that of Figure 1 for guiding the lateral displacement of the side plates 14, 15 is shown in Figures 3 and 3*a* to which reference is made. In Figure 3 the parallel-motion linkage 50 of Figure 1*b* is dispensed with and replaced by a torque tube 130 having upper and lower cantilever arms 131 and 132 respectively, each arm 131, 132 having a spigot 135 which engages in a guide slot 133 or 134 in each side plate 14. The side plates 14 are joined together at adjacent vertical edges thereof by a hinge 136, and the torque tube 130 is attached to a plenum member 20 at pivots 137, 138, in lugs 139, 140 respectively extending from the plenum member 20. An identical arrangement is provided for the side plates 15 (not shown) on the opposite side of the device. In other respects the device of Figure 3 is similar to the device of Figure 1.

In operation, lateral displacement of the side plates 14 is produced as shown by the broken lines in response to changes in hydrostatic pressure thereon in the same manner as that described in relation to the device of Figure 1, but because of the effect of the hinges 136, the train undulates along the length of the device as the waves pass along the side plates 14, 15.

The invention has been described in relation to a pneumatic circuit operated by action of the side plates 14, 15, on bellows 19*a*, 19*b* to extract energy from waves, but a hydraulic circuit may be used and operated in a similar manner.

It will be understood that resilient means (not shown) may be provided to urge return lateral movement of the side plates 14, 15.

As an alternative to the use of a fluid circuit for performing useful work from the lateral movement of the panel members, a suitable mechanism connected to the panel members may be used and arranged to drive a device such as an electric generator.

It will be appreciated that one of the advantages of the invention is that because each panel members is movable bodily, the lateral swept volume described by the panel member in response to the waves is maximised for a given maximum amplitude of motion in comparison with a member having a portion thereof restrained against lateral displacement.

In some applications of the invention, there may be advantages in constraining the lateral displacement of the panel members to the notional motion that would be produced if the panel members pivoted about a hinge located at a considerable depth below the device.

CLAIMS

1. A device for extracting energy from waves on a liquid, the device comprising at least one panel member substantially of rigid form, the panel member being arranged so as to be aligned in use substantially in the direction of motion of the waves and be exposed on one side thereof to the waves so that laterally in one direction the panel member is displaceable bodily by the pressure of the waves thereon, means for performing useful work from lateral displacement of the panel member, and means for urging return lateral displacement of the panel member as the wave pressure on said one side of the panel member falls.

2. A device as claimed in Claim 1 including means for constraining to substantially parallel motion the lateral displacement of the panel member.

3. A device as claimed in Claim 2, wherein the constraining means comprises linkage means.

4. A device as calimed in Claim 3, wherein the linkage means comprises parallel-motion linkage means.

5. A device as claimed in any one of the preceding Claims, wherein a train of said panel members is provided arranged so as to be aligned in use substantially in the direction of motion of the waves.

6. A device as claimed in Claim 5, wherein two said trains are provided, one said train on one side of the device and the other said train on the opposite side of the device.

7. A device as claimed in Claim 5 or Claim 6, wherein the panel members of the train or trains share a common work performing means.

8. A device as claimed in Claim 7, wherein the work performing means comprises a fluid circuit including at least one chamber at each panel member, said chamber having a volume arranged to be varied with said lateral displacement of the

respective panel member so as to pressurize a fluid in the fluid circuit.

9. A device for extracting energy from waves on a liquid, the device comprising a train of panel members, each panel member being substantially of rigid form and the panel members being hingedly connected together at adjacent edges thereof, means for presenting each panel member upwardly in use and such that laterally thereof the panel member is displaceable bodily, means comprising a fluid circuit for performing useful work from lateral displacement of the panel members, and means for urging return lateral displacement of the panel members, the device in use being arranged so as to align the train substantially in the direction of motion of the waves so that the variations in hydrostatic pressure on the panel members as the waves pass along one side of the train lead laterally of the panel members to bodily displacement thereof.

10. A device as claimed in Claim 8 or Claim 9, wherein the fluid circuit comprises a penumatic circuit, and includes a turbine means arranged to be driven by pressurized gas in the pneumatic circuit.

11. A device as claimed in any one of Claims 8 to 10, wherein at least some of the chambers are connected together in series relationship.

12. A device as claimed in any one of Claims 8 to 11, wherein the return urging means comprises resilient means.

13. A device as claimed in any one of Claims 8 to 11, wherein the return urging means comprises a portion of said fluid or pneumatic circuit, said portion being arranged to discharge said fluid or said gas into the chambers so as to expand said chambers.

14. A device as claimed in any one of the preceding Claims, including flexible impermeable material extending around the or each panel member to define an air filled space on the other side of the panel member so as to inhibit the ingress of the liquid to said other side of the panel member.

15. A device as claimed in Claim 14, including at least one air vent for said space.

16. A device as claimed in Claim 15, including an air turbine means arranged to be driven by the air venting through the air vent.

17. A device as claimed in any one of the preceding Claims, wherein the or each panel member is of buoyant construction.

18. A device as claimed in any one of Claims 1 to 16, wherein the or each panel member is substantially of neutral buoyancy.

19. A method of extracting energy from waves on a liquid, the method comprising presenting at least one panel member substantially in the direction of motion of the waves and exposing one side of the or each panel member to the waves, allowing the or each panel member laterally thereof to be displaced bodily by the waves thereon, and performing useful work from lateral displacement of the or each panel member.

20. A method as claimed in Claim 19, including constraining the panel members laterally thereof so as to be displaced by the waves thereon in a substantially parallel manner.

21. A method as claimed in Claim 19 or Claim 20, including presenting a plurality of said panel members in a train, and aligning said train substantially in the direction of motion of the waves.

22. A method as claimed in Claim 21, including hingedly connecting together adjacent panel members so that the train undulates along the length of the train in response to the variations in hydrostatic pressure thereon.

23. A device for extracting energy from waves on a liquid substantially as hereinbefore described with reference to Figures 1 to 1*d*, or Figures 2 to 2*b*, or Figures 3 and 3*a*.

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